

Groundwater geochemistry, hydrogeology, and coupled processes

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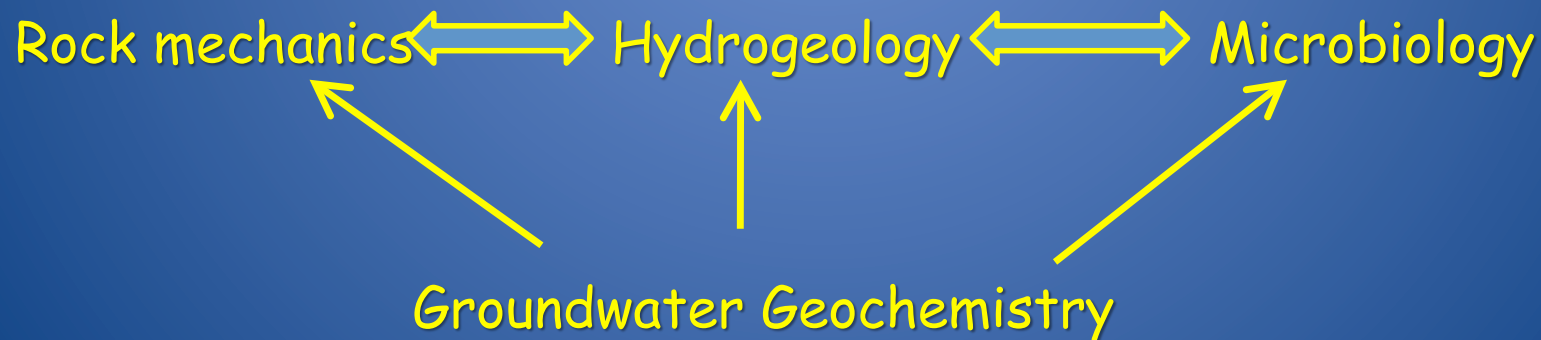


Background

- Every underground research lab has produced new discoveries in hydrogeology and water-rock interactions that were not known previously
- Although coupled processes have been broadcast for some time (see Tsang, 1988), rarely do different disciplines truly interact at the same site to either determine *in situ* coupled processes or model them and field test the models

Hydrogeochemistry

- A key interdisciplinary field that couples hydrology, geology, and chemistry and interacts with rock mechanics, microbiology, and thermal experiments



Development of URLs

1. Radioactive waste disposal research
2. Deep microbiological research
3. Particle physics experiments
4. Deep wells for geological research
(major structures, fault zones,
seismically active areas, stable areas;
Kola superdeep, San Andreas, etc.)

International Stripa Project

1977-1994

- To investigate the properties of a granite to contain high-level nuclear waste; experiments were performed on:
 - Rock mechanics
 - Hydrogeology
 - Geophysics
 - Geochemistry (water-rock interactions)

Between this project and the Swedish program, hundreds of reports were produced (and numerous other EU programs)

Effect of heater experiments on groundwater chemistry, Stripa, Sweden

Heating the rock caused a rapid increase in concentration followed by a larger decrease in concentration

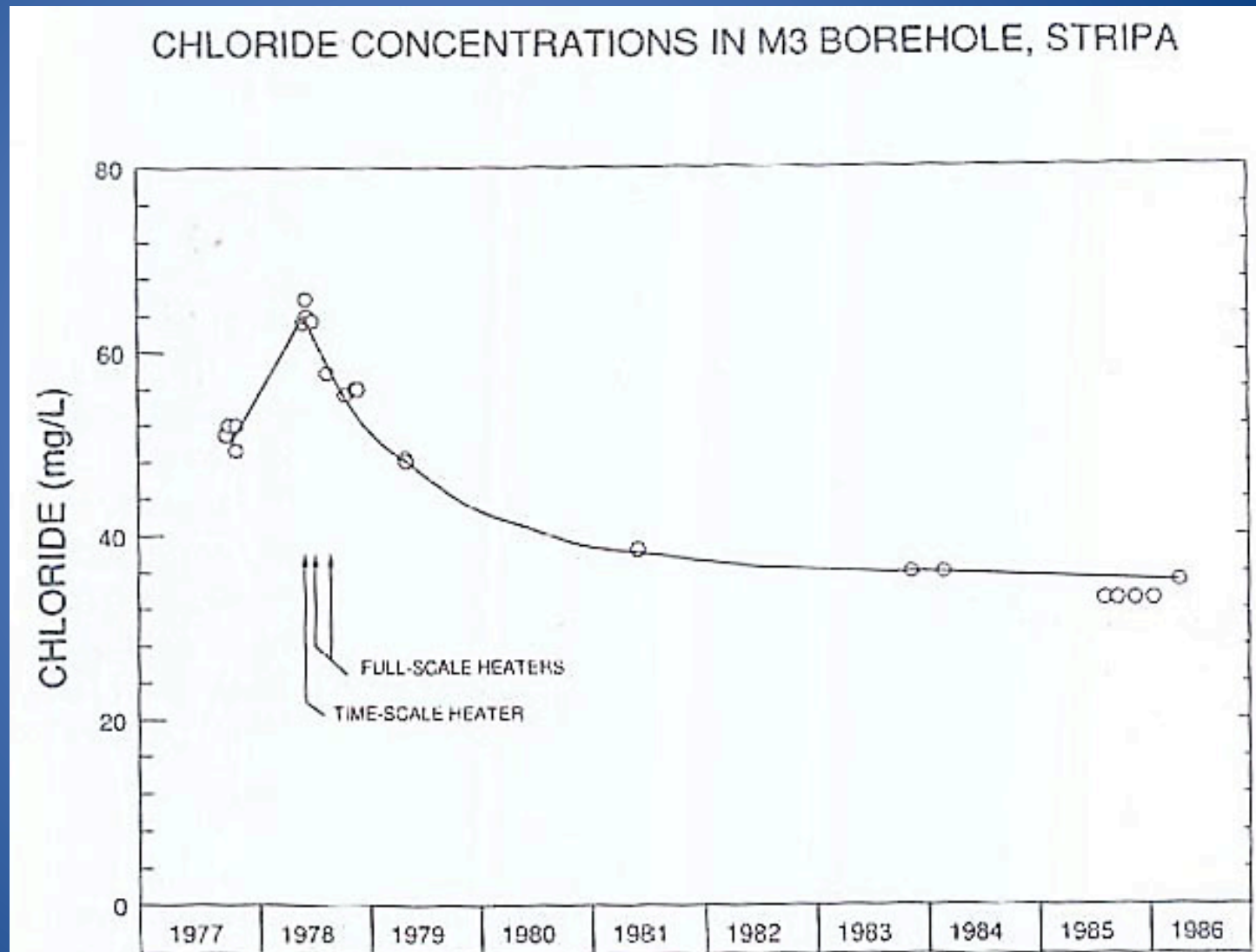


FIG. 4. Chloride concentrations in M3 borehole as a function of time.

Äspo URL

- Lithology has some similarities to Stripa but groundwater chemistry was much more complex; possible 5 end-members mixing
- Although studies went further than Stripa in some sense, different geochemists did not reach a clear consensus on the interpretation of water-rock interactions

URL at Pinawa, Manitoba

- Highly anisotropic behavior observed in rock mechanic studies
- These were found to relate to anomalous pressure gradients from the hydrogeologic studies
- Probably related to strong gradients in groundwater chemistry

What is different or unique about DUSEL hydrogeochemistry?

- Proterozoic metamorphic, mineralized aquifer - rarely been studied and never to these depths
- Possibility for drilling into "fresh" rock at different depths to determine geochemical evolution of groundwater (and evolution of deep groundwater as it enters the mine environment) like at Stripa but deeper and different rock type
- "natural background" mobility of trace elements in a mineralized aquifer at considerable depth
- Possibility for applying a range of stable and radioactive isotopes to constrain the geochemical evolution
- Provide the solution chemistry (major ions, trace elements, redox species, nutrients) for microbial habitats and for deep mine redox reactions

Lessons learned from Stripa

- Little known report written by Andrews, Fontes, Fritz, & Nordstrom summarizing what we had found out from our 10 years of investigations at Stripa including a table of all known isotopes and what information they can provide

Technique development

- Multiple use sampling holes - how best to plan for and sample holes that might be used for water chemistry, gas sampling, microbiology, rock mechanics, hydrogeology, thermal studies
- Chem lab on site (at depth) for processing samples, back up equipment, GC, etc. Small space needed, perhaps combined with microbiol modular unit

Hydrogeology

- Chemical and isotopic compositions can provide the necessary constraints on flow paths and residence times that Larry Murdoch and David Bout need in the groundwater models they are developing (e.g. application of young groundwater age dating techniques, CFCs and $^3\text{H}/\text{He}$ methods, combined with ^{14}C)

Weathering study and geochemical evolution of groundwater

- Mineral weathering rates as a function of depth, temperature, rock type
- Test and evaluate the ability of geochemical models to model mineral solubilities as a $f(T)$
- Drill new holes in relatively unperturbed parts of the same rock at different depths and T (then same with another rock type)
- Obtain age dates/residence times, get mineral dissolution rates; interpret water mixing
- Obtain redox species (Fe(II/III) , As(III/V)); look for Fe-oxidizers/ reducers, As-oxidizers/ reducers

Gas sampling

- With an on site GC unusual reactive gases could be monitored to complement microbiological studies; rapid determinations of hydrogen, oxygen, methane, C-S volatiles, etc. can be made
- Noble gases can assist with interpreting recharge conditions and water mixing

Database management

- *Geochemical data*
 - *Minerals*
 - *Water (historic and current)*
- *Microbiological data*
- *Hydrological data*